CLAIMS

1. A method for determining areal densities of bone, fat and soft tissue in a localized area of a patient, comprising the steps of:

(a) collecting data defining an x-ray energy transmission curve by scanning the area of the patient at a plurality of points with a collimated x-ray beam and detecting and measuring beam intensity after having passed through the patient at a plurality of different energies at each point;

(b) selecting from a database of x-ray spectral curves a spectral curve corresponding to the transmission curve defined by the collected data, wherein each spectral curve relates beam energy to beam intensity at each beam energy;

(c) defining a curve relating the logarithm of the ratio of beam intensity in air divided by the measured beam intensity after passing through the patient for each of a plurality of photon energies in the beam;

(d) solving a matrix equation for a solution comprising the sum totals of the areal densities of bone, fat and soft tissue in response to predetermined mass attenuation coefficients for bone, fat and soft tissue at a group of three selected energies and in response to the logarithmic ratio obtained from the curve at each of the three selected energies;

(e) repeating step (d) a plurality of times, each time obtaining a solution by solving the matrix equation at a group of three selected energies different from the group at which the matrix equation was previously solved;

(f) computing an average of the sum total of the areal densities of bone from the solutions obtained in step(e), an average of the sum total of the areal densities of fat from the solutions obtained in step (e), and an average of the sum total of the areal densities of soft tissue obtained in step (e); and

(g) performing an iterative method to estimate the areal densities of bone, fat and soft tissue in response to the sum totals of the areal densities of bone, fat and soft tissue.

2. The method recited in claim 1, wherein the step of scanning the area of the patient at a plurality of points with a collimated x-ray beam and detecting and measuring the beam intensity after having passed through the patient at a plurality of different energies at each point comprises the step of passing the beam through a plurality of different thicknesses of an attenuative material at each point.

3. The method recited in claim 1, wherein the step of scanning the area of the patient at a plurality of points comprises the step of scanning the patient in a raster fashion along two axes.

4. The method recited in claim 1, wherein the step of selecting from a database comprises the steps of:

(h) determining the x-ray photon energy spectra in air at a plurality of photon energies in the x-ray spectrum as a function of kVp, mA, and transmitted through different filter material placed in the x-ray beam using measurements with a spectrometer system, analytical calculations, Monte Carlo calculations and interpolation to form a database of x-ray spectra in air;

(i) determining a transmission curve for the spectra determined in step (h) in response to filters of different thicknesses at each point in the patient;

(j) matching the transmission curve for the x-ray spectra determined in step (h) to the transmission curves in the data base to identify an x-ray energy spectrum that is transmitted through the patient at a plurality of points;

(k) forming a quantity at each useful photon energy, Ei, in the in air and transmitted x-ray spectra which is the logarithm of Io(Ei)/I(Ei) with Io denoting the in air beam and I the transmitted beam;

(l) selecting three energies to a form a 3x3 matrix with each row of the matrix equal to the value formed in step (k) at the energy Ei with the matrix being filled by the mass attenuation coefficients of soft tissue, fat and bone at the energies Ei selected for each row;

(m) solving for areal density of soft tissue, fat and bone for each set of three energies selected in step (l);

(n) repeating steps (l) through (m) for a plurality of different energies each and forming the sum of the total areal density of soft tissue, fat and bone derived by each solution; and

(o) forming the average value of the total areal density of soft tissue, fat and bone by dividing the sum formed in step (n) by the total number of solutions.

5. The method recited in claim 4, wherein the step of performing an iterative method comprises the steps of:

(p) making a first guess as to the areal density of two components with the areal density of the third component derived by subtracting the estimated areal density of two components from the known total areal density;

(q) calculating the quantity recited in step (k) in response to the estimated areal densities of the three components;

(r) in a step-by-step fashion performing the calculation recited in step in (q) and forming the difference between the calculated quantity using the estimated areal densities and the quantity formed in step (d);

(s) forming the total sum of the differences for estimated areal densities;

(t) repeating steps (p) through (s) a plurality of times using different estimates of the individual areal densities and forming the sum of the total differences each time; and

(u) selecting a set of areal densities having the smallest total sum difference between the two curves as characterizing the correct or true areal densities of soft tissue, fat and bone at that location.